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ISO Study of Operational Requirements and Market Impacts at 33% RPS

Continued Discussion and Refinement of Step 1 and Step 2 Simulation Methodology

CPUC Workshop on

CAISO and PG&E Renewable Integration Model Methodologies

October 22, 2010

Contents of Presentation

1. Objectives and Approach of 20% -33% RPS studies
2. Alternative Approaches to Representing Future Load-following and Regulation Requirements
3. Ex ante Analysis of Fleet Capabilities in the 2020 Simulation Models
4. Status of Production Simulation Results and Next Steps
5. Question and Answer Period on all Materials Released To Date

OBJECTIVES AND APPROACH OF ISO 20%-33% RPS STUDIES

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Objectives (1)

1. Identify operational requirements and resource options to reliably operate the ISO controlled grid (with some assumptions about renewable integration by other Balancing Authorities) under 20% to 33% RPS in 2020
   - Estimates of hourly and sub-hourly integration requirements (measured in terms of operational ramp, load following and Regulation capacity and ramp rates, as well as additional capacity to resolve operational violations)
   - Consideration of additional variables that affect the results
     - Impact of different mixes of renewable technologies and other complementary policies
     - Impact of forecasting error and variability

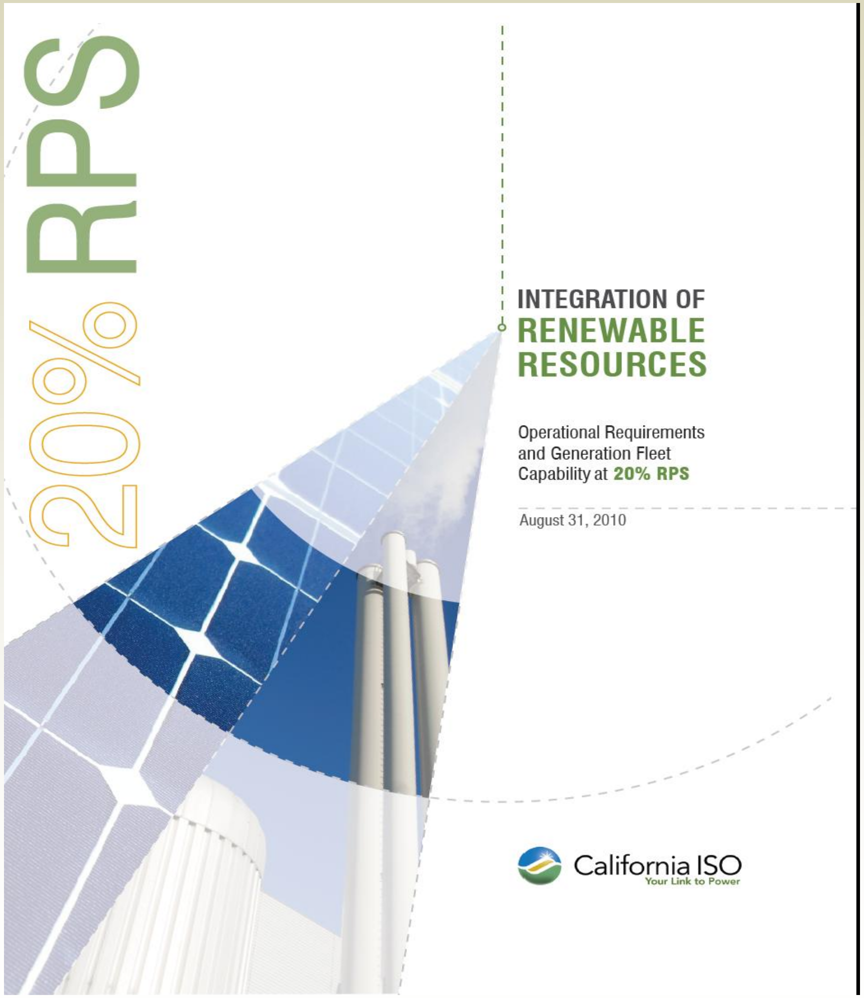
Objectives (2)

2. Inform market, planning, and policy/regulatory decisions by the ISO, State agencies, market participants and other stakeholders

   - Support the CPUC to identify long-term procurement planning needs, costs and options
   - Inform other CPUC, and other State agency, regulatory decisions (Resource Adequacy, RPS rules, once through cooling (OTC) schedule, and so on)
   - Inform ISO and state-wide transmission planning needs to interconnect renewables up to 33% RPS
   - Inform design of ISO wholesale markets for energy and ancillary services to facilitate provision of integration capabilities

ISO study of renewable integration at 20% RPS

• Published August 31, 2010
• First detailed operational study of its kind to consider both wind and solar resources at high RPS
•Parties interested in the 33% RPS simulations should also read this study
• Study and comments available at http://www.caiso.com/27be/27beb7931d800.html



Technical appendices for integration studies

- Published October 11, 2010
- Intended to cover both 20% and 33% RPS studies
- First draft for external review
- Draft appendix and initial round of comments available at http://www.caiso.com/27be/27beb7931d800.html

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Integration of Renewable Resources:

Technical Appendices for California ISO Renewable Integration Studies

Version 1

FIRST DRAFT FOR EXTERNAL REVIEW
October 11, 2010

Technical appendices -- contents

A. CAISO market scheduling processes and timelines
B. Profiling and determination of forecast errors for load and wind/solar generation
C. Methodology for statistical analysis of operational requirements
D. Methodology for production simulation models
E. Empirical analysis of historical ISO data

Study approach – overview of modeling tools utilized and proposed for LTPP methodology

- *Step 1* – Statistical Simulation to Assess Intra-Hour Operational Requirements
  - Estimates added intra-hour requirements under each studied renewable portfolio due to variability and forecast error
  - Calculates the following by hour and season: Regulation Up and Regulation Down capacity, load-following up and down capacity requirements, and operational ramp rate requirements
- *Step 2* – Production Simulation
  - Dynamic optimization model that simulates system least-cost commitment and dispatch of resources to meet load, ancillary services and other requirements in an hourly time-step.
  - Uses Step 1 Regulation and load following capacity results as additional requirements to meet intra-hourly requirements
  - Calculates the following by hour and season: production cost-based energy prices, emissions, energy and ancillary services provided by units, violations of system constraints and additional capabilities required to eliminate those violations

Study approach – interpretation of results

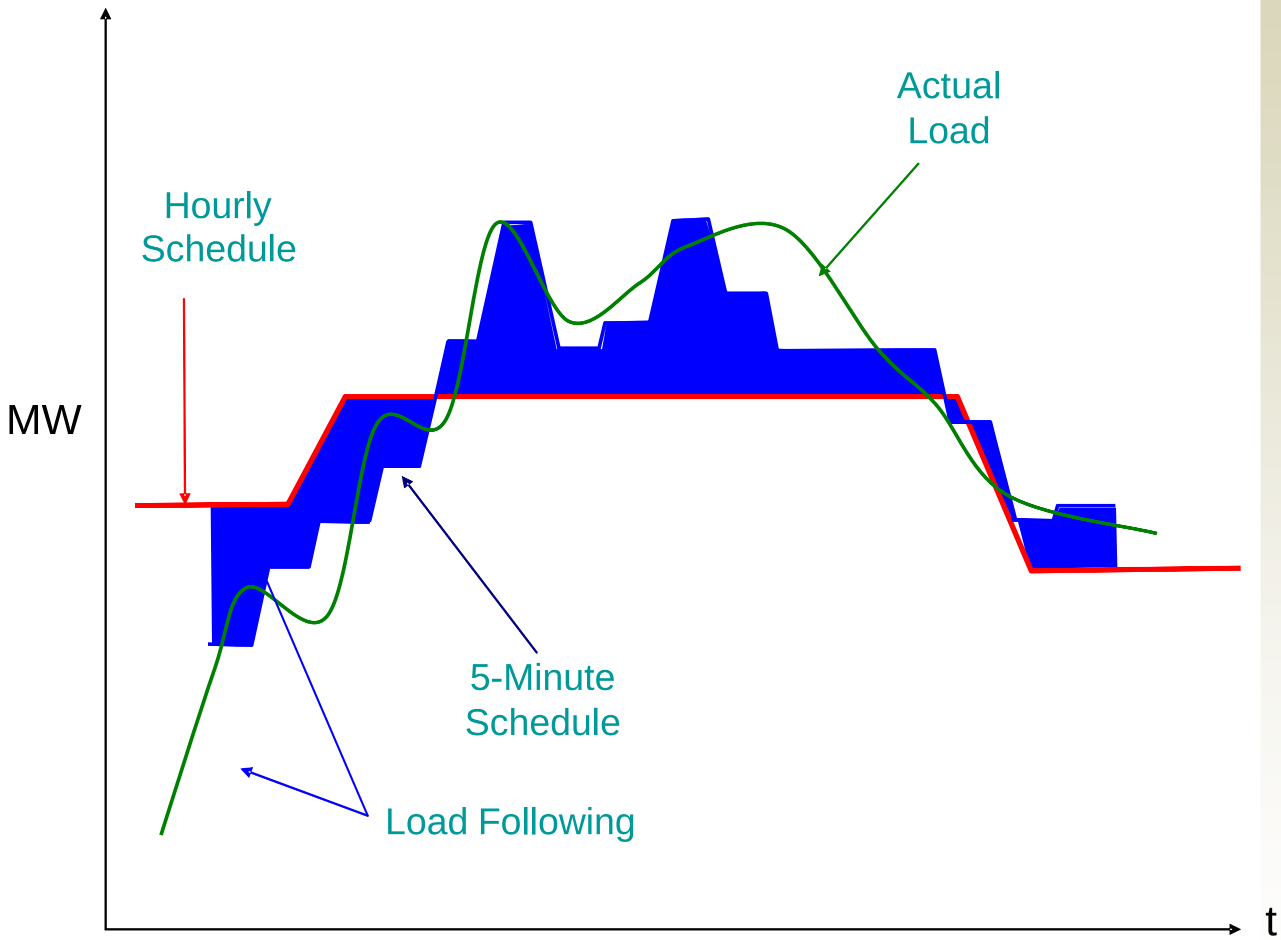
- Simulation results need careful interpretation (discussion in following slides)
- The simulation model methods are well understood and supported; technical documentation is available and becoming more complete
- However, the models are complicated and have a large number of inputs and outputs
- Sensitivity analysis gives further insight into results
- Observation and conclusions should be reserved until the final results are available

Overview of key operational impacts being studied

- Increased frequency and magnitude of system ramps across various time-frames (minutes, hours)
- Increased load-following up and down requirements (intra-hourly deviations from hourly schedules), perhaps leading to needs for additional reserves
- Increased requirements for Regulation Up and Regulation Down (minute by minute requirements within five minute dispatch intervals)
- Increased frequency and magnitude of overgeneration conditions (hours)

DETERMINATION OF LOAD-FOLLOWING AND REGULATION REQUIREMENTS FOR PHASE 1 OF PRODUCTION SIMULATIONS

Load Following requirement is shown as the blue shaded area

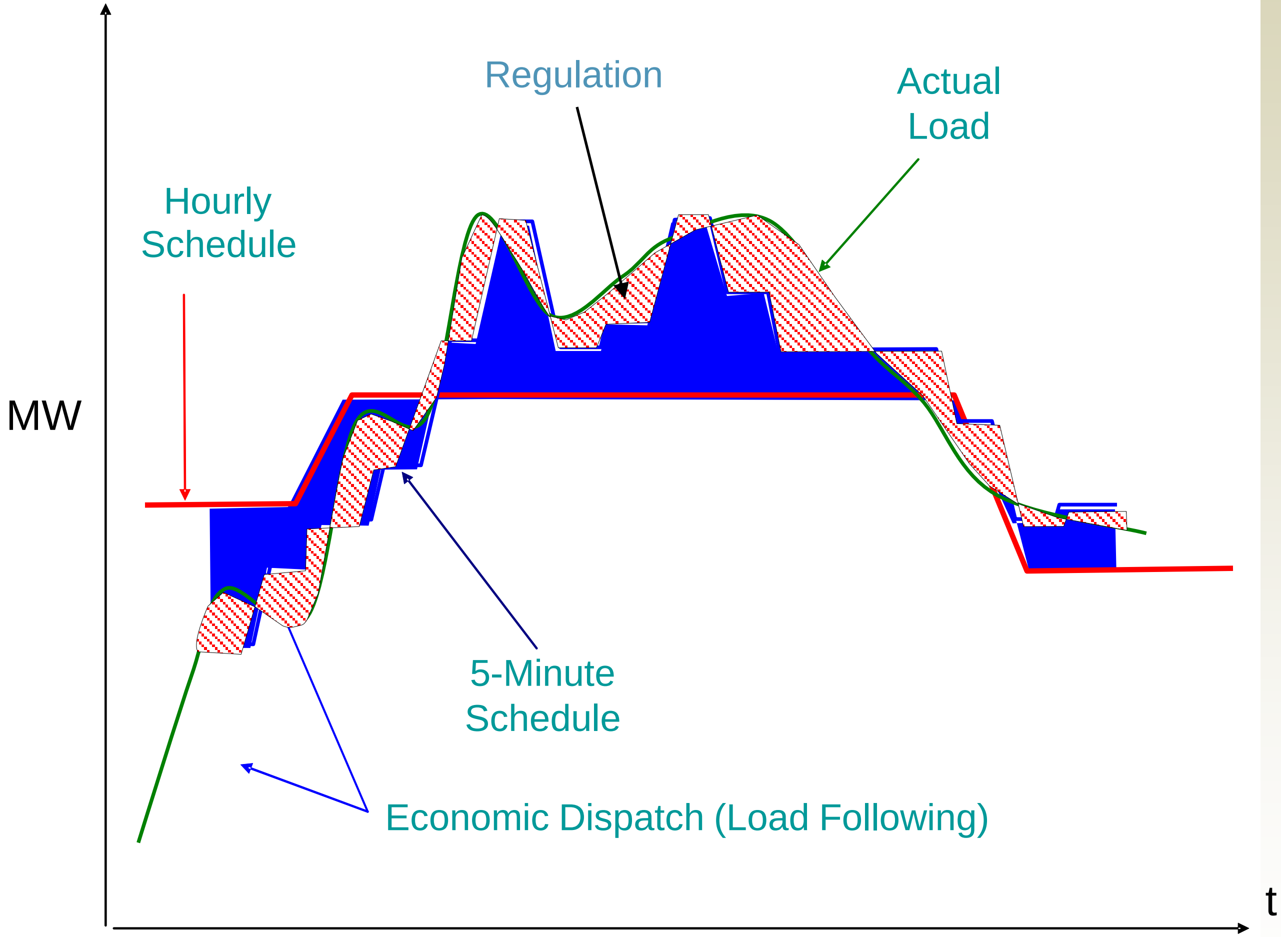


Note : This figure does not reflect an actual scheduling interval

Three types of load-following results in both the upwards and downwards directions

- Load following maximum “capacity” requirement for each hour [MW, hourly value]
  - Defined as the largest gap between the simulated hourly schedule and any five minute dispatch interval
  - Input into Step 2 production simulation model
- Load following ramp rate [MW/min]
  - Defined as the largest per-minute change required to meet the load following capacity requirement
- Load following ramp rate duration
  - Calculated ex post as the longest sequence of 5 minute dispatch intervals that sustain a particular ramp rate within any hour or series of hours

Regulation requirement is shown as red shaded area



Note : This figure does not reflect an actual scheduling interval

Three types of regulation results in both the upwards and downwards directions

- Regulation maximum “capacity” requirement for each hour [MW, hourly value]
  - Defined as the largest gap between the simulated five minute dispatch interval and any one minute interval within that five minute interval
  - Input into Step 2 production simulation
- Regulation ramp rate [MW/min]
  - Defined as the largest difference between any two contiguous 1 minute capacity requirements within a 5 minute interval
- Regulation ramp rate duration
  - Calculated ex post as the longest sequence of 1 minute intervals that sustain a particular ramp rate within any regulation 5 minute interval

Outline of modeling issues to resolve

- Forecast error assumptions in Step 1 (input to Step 1)
- Statistical range of capacity requirements modeled in Step 2 (output of Step 1)
- Which hourly values are modeled (output of Step 1)
- Residual vs. total load-following requirements
- Whether to model load-following down constraints

Effect of forecast error assumptions

- Forecast error assumption (input to Step 1):
  1. Forecast errors based on current forecast error statistics
  2. Improvements in current forecast errors
  3. No forecast errors (to benchmark the impact of forecast errors versus inherent variability of the 1-minute data)
- For the 20% RPS study, the ISO used current forecast error statistics
- For the 33% RPS study, the ISO has chosen “improved error” assumptions for load, wind and solar
  - Exact assumptions shown in draft technical appendix, pg. 42

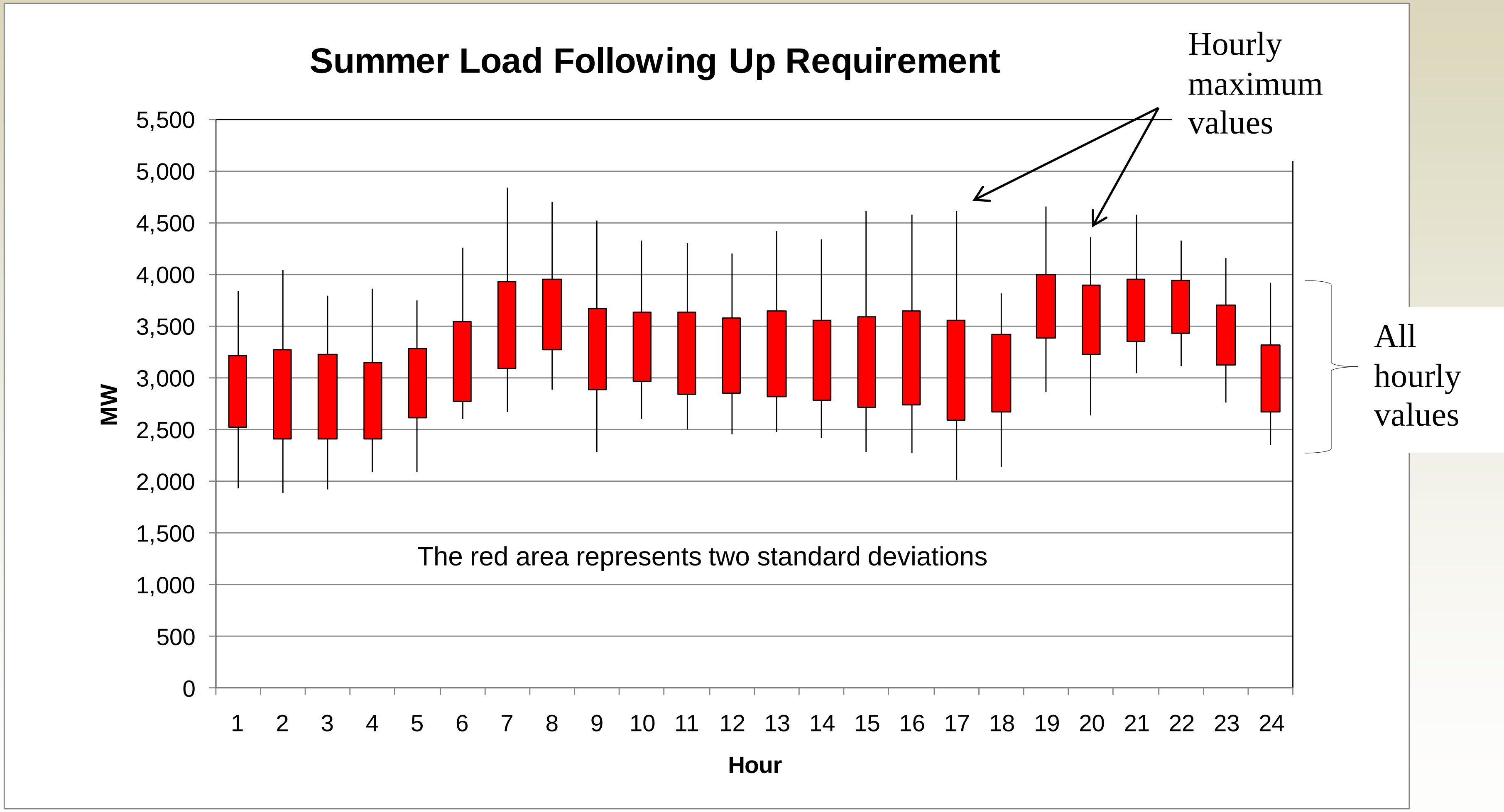
Statistical range of results to model

- Statistical range of load following and regulation requirements modeled (output of Step 1):
  1. 95th percentile of values using 3 standard deviations or max. capacity (current approach)
  2. Less than 95th percentile, e.g., 2 standard deviations (~83% of values for a normal distribution)
- ISO recommends retaining the current approach
  - Using a lower range of values implies that during events in the extreme range of possible values, either there are more violations of (current) reliability standards or more renewable energy is dumped
  - Better to retain the higher requirement and understand the impact on operations

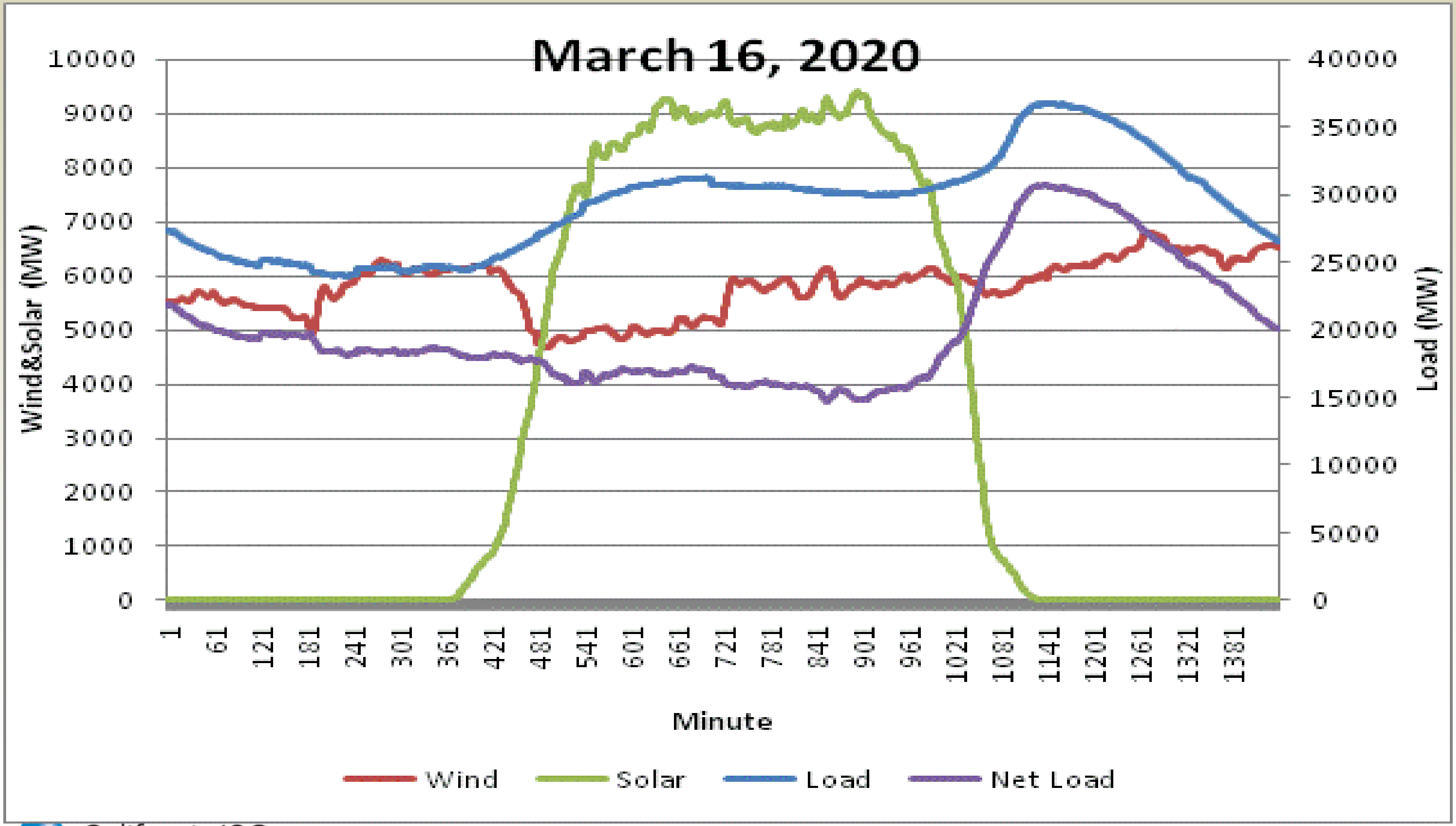
Hourly values modeled

- Hourly values of load following and regulation requirements modeled from iterations of the statistical model (output of Step 1):
  1. Seasonal maximum hourly values by hour of day (i.e., max. for hours 1 to 24)
  2. Simulated maximum values for all hours in season (i.e., max. for hours 1 to 2180)
  3. Other?
- ISO recommends using the values for all hours from the simulation
  - Will not affect the determination of any additional capability needed over PRM
  - Will affect estimates of emissions, fuel use, net imports
  - See explanations on pgs 58-60 and 80 of technical appendix

Example: Summer 2020 load following up capacity requirement, distribution of summer hourly results – 33% RPS Reference Case



Example: Profiles for March 16, 2020, 33% Reference Case



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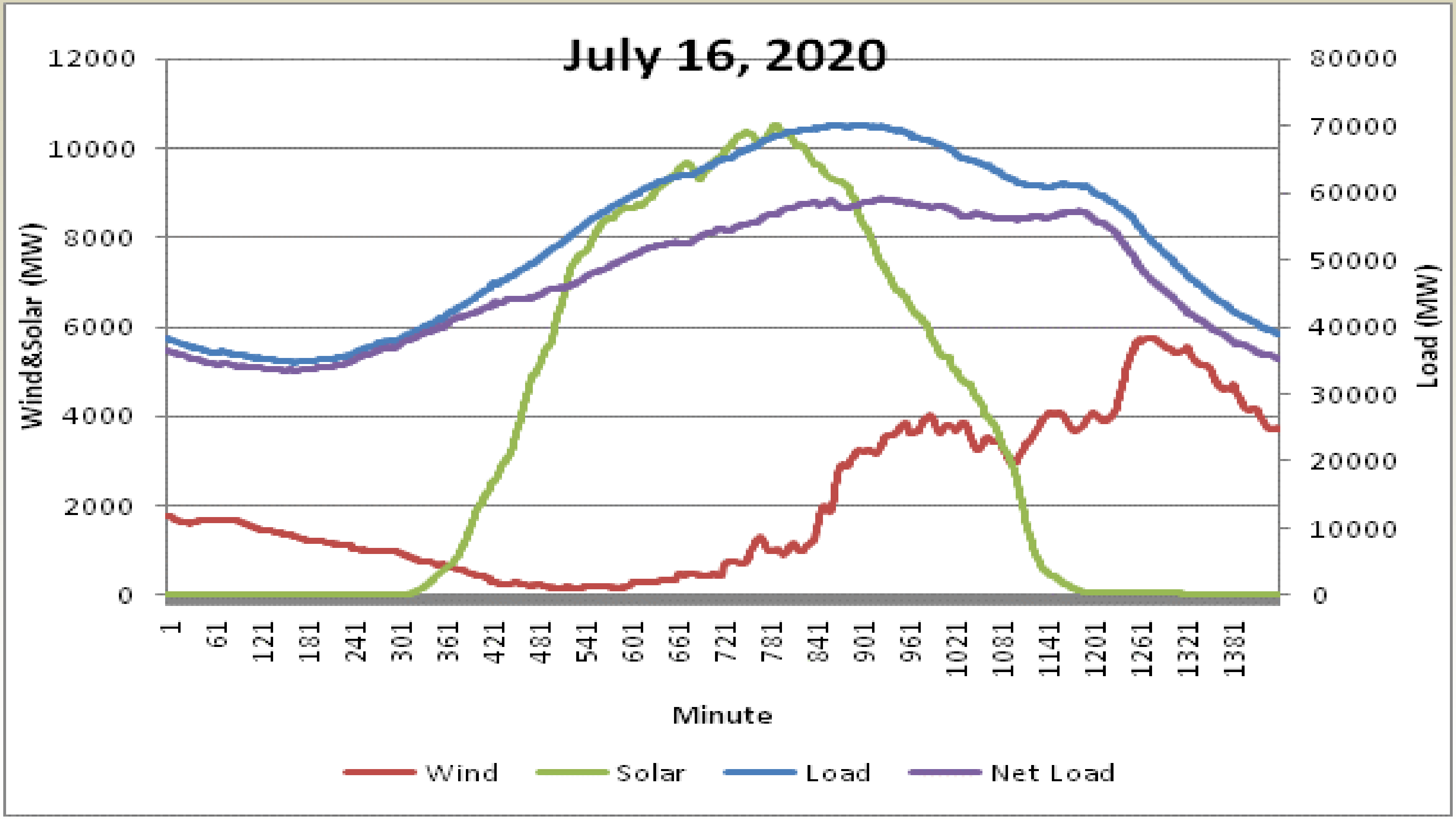
Example: Profiles for July 16, 2020, 33% Reference Case



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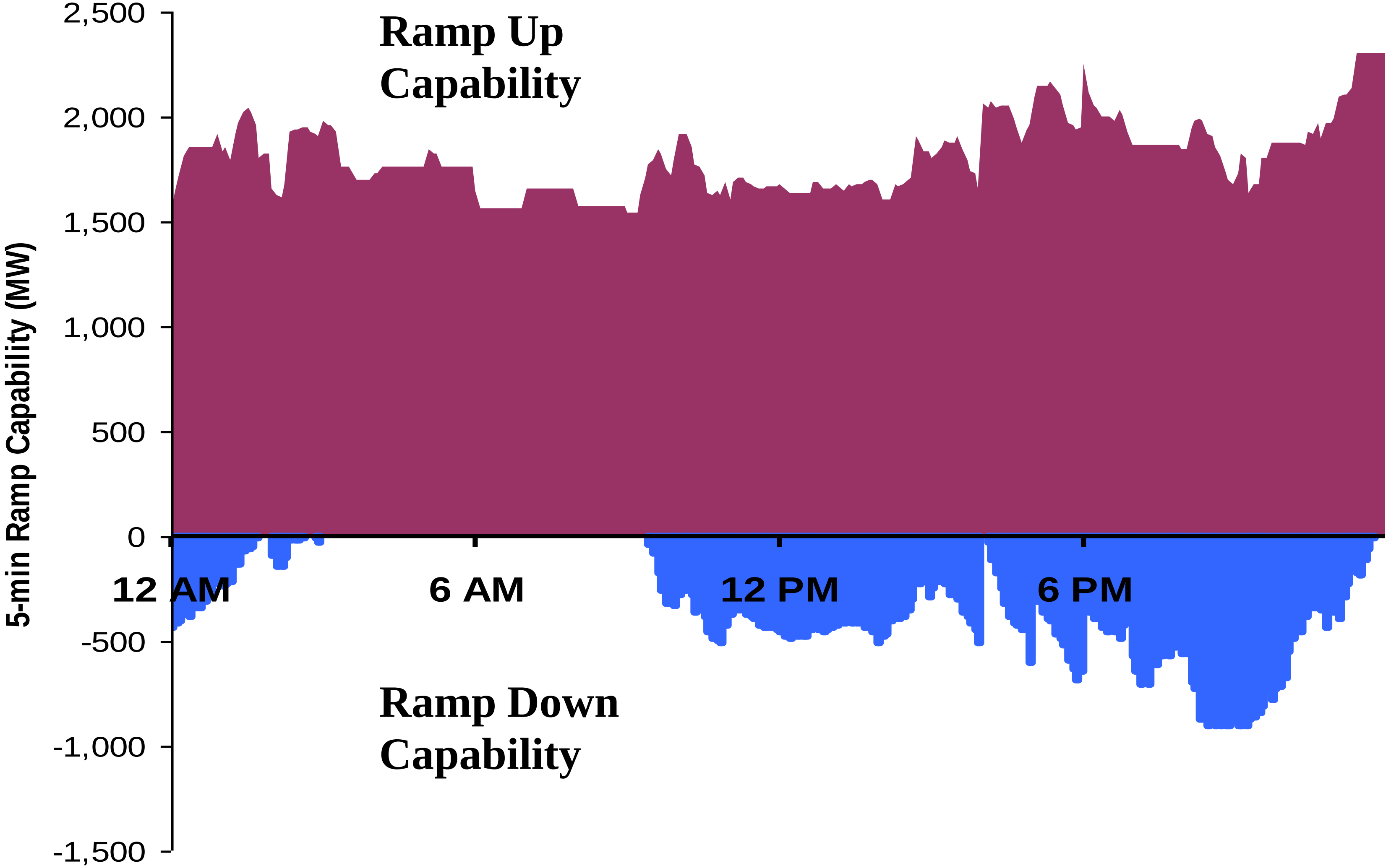
Residual vs. total load-following requirement

- Residual vs. net load following capacity values modeled from iterations of the statistical model (output of Step 1):
  1. Total hourly load following capacity requirement from Step 1
  2. Residual hourly load-following requirement determined through additional analysis of each hour
- ISO will use the total hourly value, but will do additional analysis of the results to determine whether and how much of an overestimate of additional upwards requirements that might be based on the daily load shape and simulated commitment and dispatch

Residual vs. total load-following requirement (2)

- In the current dispatch, upwards load-following capability on a 5-minute basis appears to be highest as the morning upwards ramp begins, is lowest during the midday hours, and fluctuates over the rest of the day
  - See discussion in Section 4 and Appendix B of the 20% RPS integration study
- Five-minute simulations of selected days can help clarify the inherent upwards and downwards capability within and across hours (see next slide)
  - Need to consider both forecast error and variability
  - Too computationally intensive to do for all hours
  - See discussion in Section 5 and Appendix C of the 20% RPS integration study

Example: Simulated upward and downward 5-minute load-following capability, May 28, 2012, during high hydro, high wind conditions



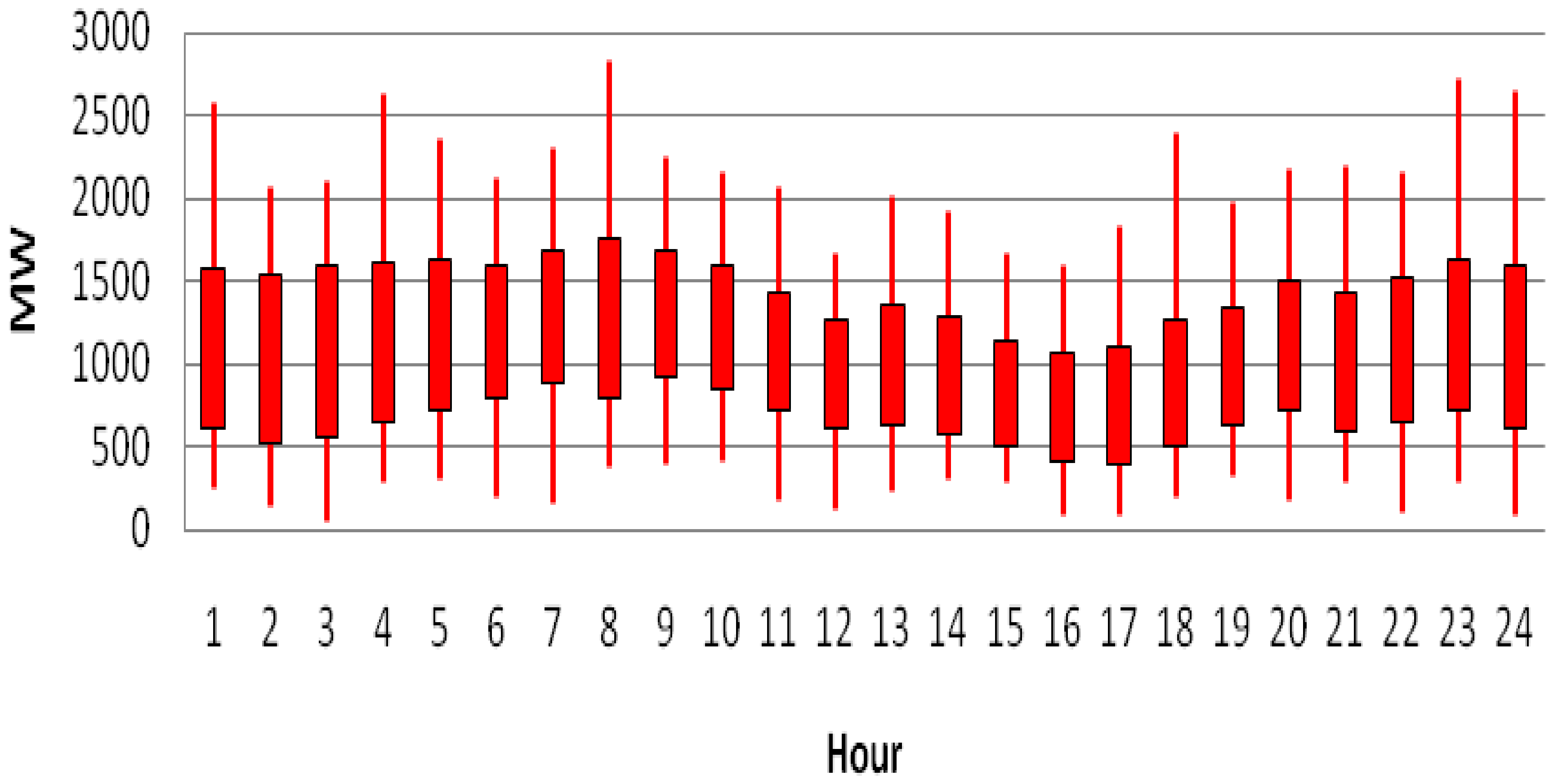
Modeling of load-following down constraints

- Operationally the system is more flexible in a downwards direction *in most hours* than in an upwards direction.
  - This is because all *dispatchable* units that are operating can be ramped down (within their operating constraints) but only the marginal units can be ramped up
- In some hours and under some system conditions, the power system is ramp/capacity constrained in a downward direction

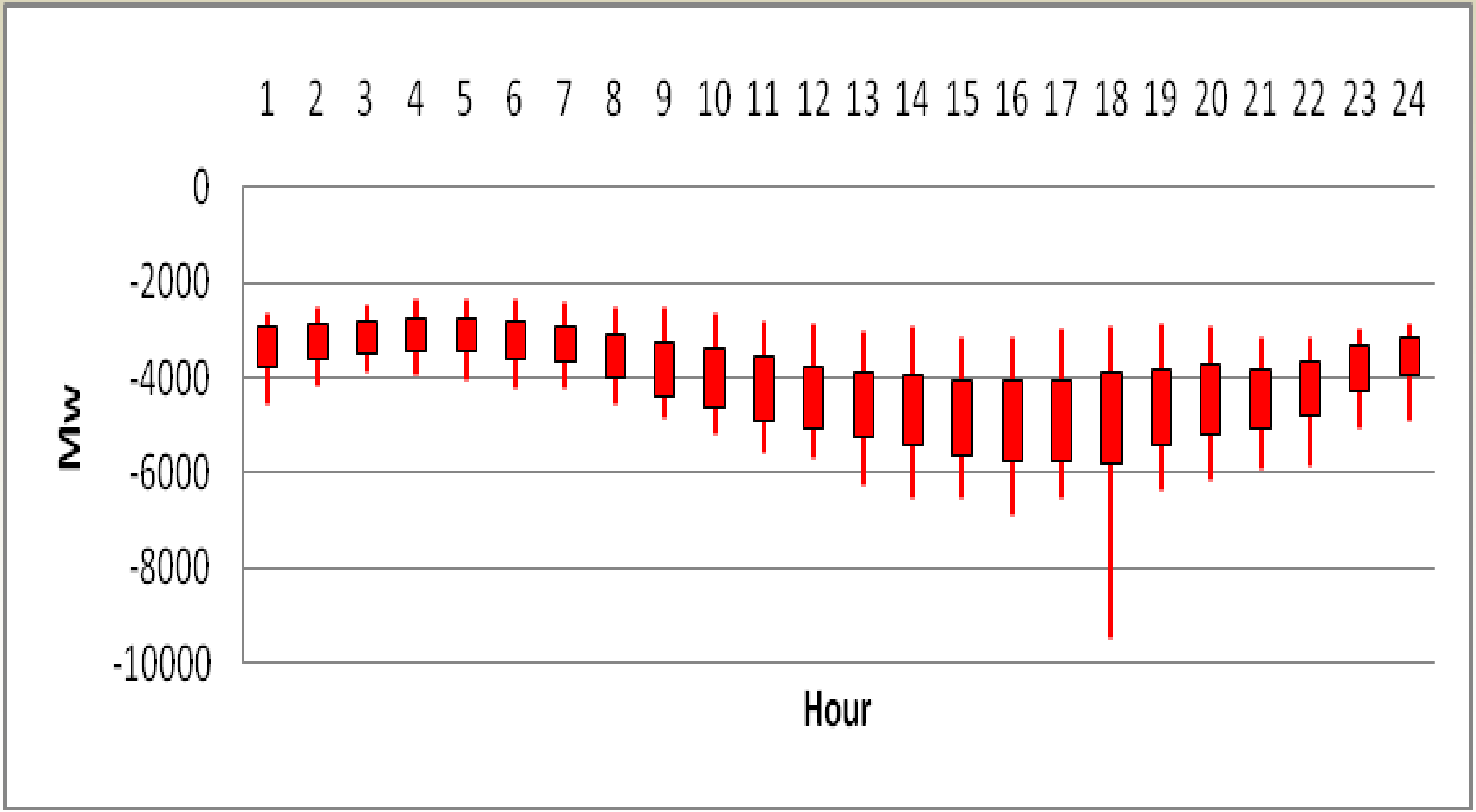
Modeling of load-following down constraints (2)

- In those hours, this can be managed through additional units (or storage or upwards demand response) that would be needed to be committed to provide downward dispatch capability *or* curtailment of renewable production *or* exports (hourly if anticipated prior to hour; intra-hour only if intertie schedule intervals are sufficiently flexible)
- Additional commitments of conventional generation may further exacerbate the potential for overgeneration and increase emissions and fuel costs

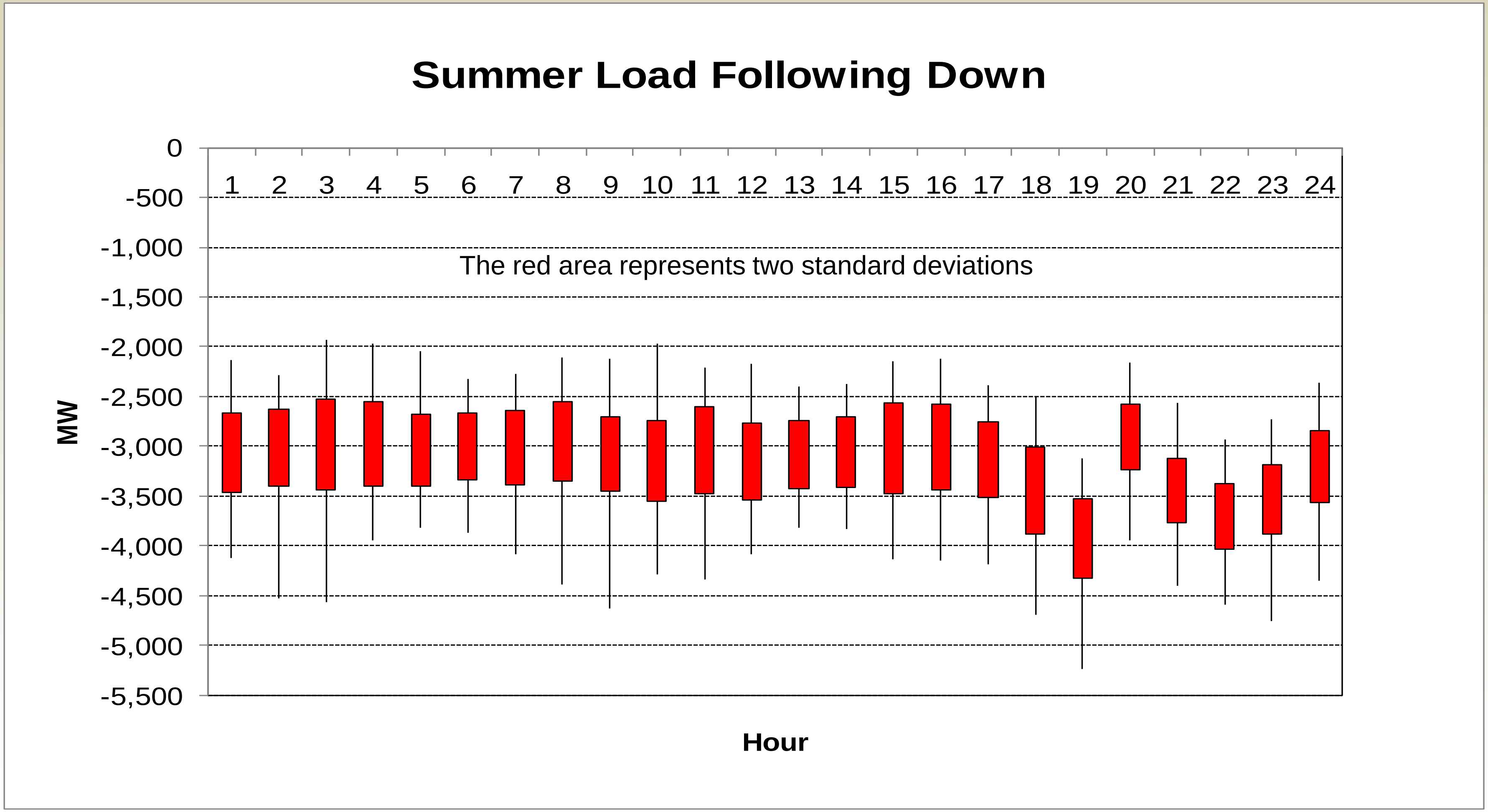
Summer upward 5-minute load-following capability, 2009 and June 2010



Summer downward 5-minute load-following capability of thermal units, not limited by self-schedules, 2009 and June 2010



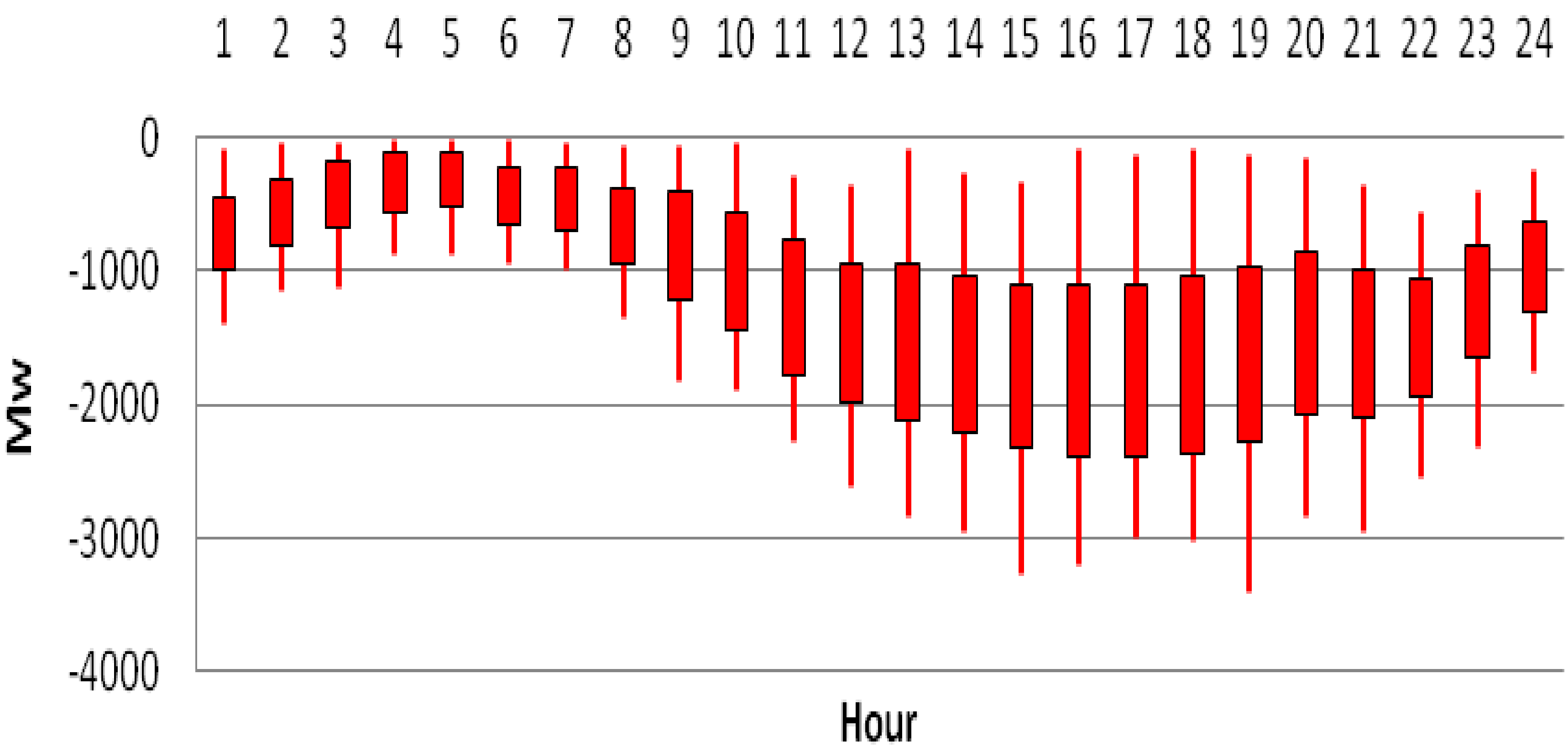
Summer 2020 load following down capacity requirement, distribution of summer hourly results – 33% RPS Reference Case



Load-following down is currently constrained by self-schedules

- A self-schedule is an instruction to the ISO to operate a plant at a fixed level of output by hour (can vary over the day)
- E.g., operate at 200 MW in hour 1, 300 MW in hour 2, etc.
- Otherwise flexible units are self-scheduled due to
  - Contractual reasons
  - Operational reasons, e.g., concerns that the ISO dispatch will violate operating constraints (e.g., forbidden regions in combined cycles)
- ISO will generally not account for self-schedules in production simulations

Summer downward 5-minute load-following capability, limited by self-schedules, 2009 and June 2010



Issues for modeling load-following down capacity in Step 2

- Whether or not to model a load-following down constraint in the 33% RPS simulations
- If yes, what should be the magnitude of the constraint
- ISO plans on performing sensitivities to illustrate impact of load-following down constraint on modeling results

SECTION 3: COMPARISON OF FLEET FLEXIBILTY

Analysis of generation fleet flexibility in 2020

- Analyzed the flexibility of the fleet represented in each of the 2020 cases studied
- Background
  - Significant number of flexible unit retirements assumed (OTC and others that total 15,701 MW) with only 9,404 MW planned additions assumed
  - Capacity credit given to renewables (NQCs) in PRM buildout increases with increasing % of renewables (33% Reference Case credit is 11,654 MW)
  - Thus units needed to be added to meet PRM decrease with increasing renewables which results in less flexibility added when meeting PRM
  - Units added to meet PRM deficiencies were flexible GT units
  - Regulation and LF requirements increase with level of renewables thus increasing the need for flexibility

Analysis of generation fleet flexibility in 2020 (2)

- Result
  - Flexibility of the fleet reduces with higher levels of renewables when meeting 17% PRM requirements – Reg and Load Following capability in 33% Ref Case are 40% less than in the All Gas Case
  - 33% fleet at 17% PRM has only slightly more flexibility than the system after the OTC retirements and currently planned additions are considered

Analysis of generation fleet flexibility in 2020 (3)

	B	C	D	E	F	G	H	I
5	Case Name		All Gas Final	20% Final	27.5% Final	33% Final	High DG PRM Only	High OOS PRM Only
6	Data Summary (2020)	Common In All Cases	All Gas Case	20% RPS	Alt 27.5% RPS	33% RPS Reference	33% RPS High DG	33% RPS High OOS
7	**Existing Resources That Do Not Provide Regulation or Load Following**							
8	Hydro Run of River	890	890	890	890	890	890	890
9	Cogen	4,358	4,358	4,358	4,358	4,358	4,358	4,358
10	Demand Response	0	0	0	0	0	0	0
11	Imports net	13,000	13,000	13,000	13,000	13,000	13,000	13,000
12	Renewables	2,897	3,161	3,196	2,877	2,897	2,967	3,174
13	**Existing Resources That Provide Regulation or Load Following**							
14	Existing Thermal net of OTC & retired	23,177	23,177	23,177	23,177	23,177	23,177	23,177
15	Hydro Dispatchable	6,337	6,337	6,337	6,337	6,337	6,337	6,337
16	Pumped Storage	3,271	3,271	3,271	3,271	3,271	3,271	3,271
17	**Total Existing Resources**							
18	Total	53,931	54,195	54,230	53,911	53,931	54,001	54,207
19	**Planned Additions Common to all Cases**							
20	Planned Thermal	9,404	9,404	9,404	9,404	9,404	9,404	9,404
21	Incremental DR	0	0	0	0	0	0	0
22	**Existing and Planned Resources That Provide Regulation or Load Following**							
23	Existing & Planned w Reg & LF	42,189	42,189	42,189	42,189	42,189	42,189	42,189
24								
25	Regulation Up Requirement Summer Max		366	577	892	1,114	1,341	918
26	Load Following Up Requirement Summer Max		4,003	4,289	4,448	4,841	6,443	5,124
27	Requirements Relative to All Gas - Reg			211	526	748	975	552
28	Requirements Relative to All Gas - LF			286	445	838	2,440	1,121
29								
30	**Incremental Renewables and Additions to Meet 17% Planing Reserve Margin**							
31	Inc Renewables		0	3,349	9,073	11,653	14,518	7,420
32	Generics to meet (17%) PRM		13,400	10,050	4,600	2,000	0	6,100
33	**Total Resources at 17% PRM**							
34	Total	63,335	76,998	77,032	76,987	76,988	77,922	77,132
35	**Total Resources (MWs) at 17% PRM That Provide Regulation and Load Following**							
36	Total	42,189	55,589	52,239	46,789	44,189	42,189	48,289

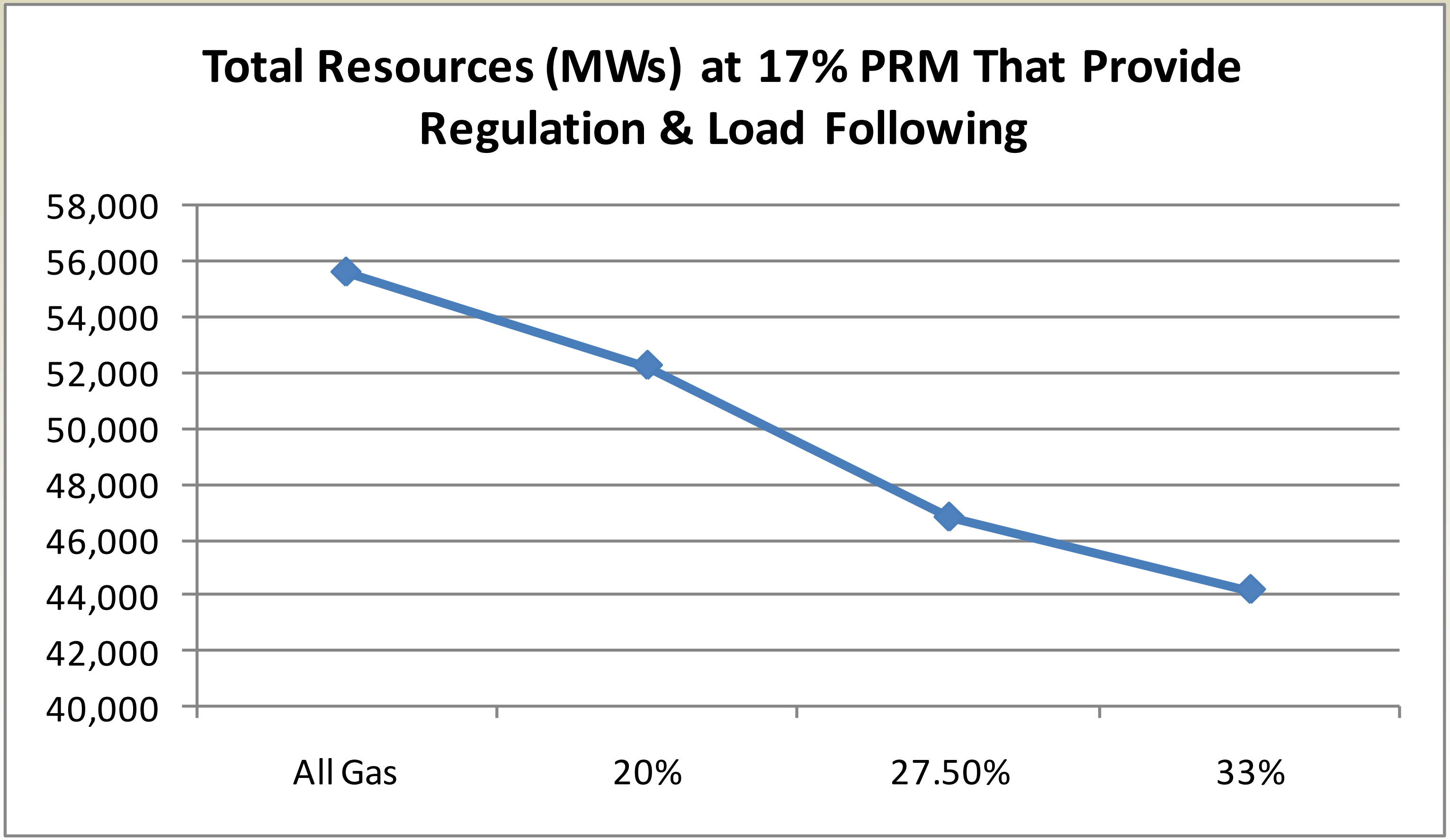
Analysis of generation fleet flexibility in 2020 (4)

Case Name		All Gas Final	20% Final	27.5% Final	33% Final	High DG PRM Only	High OOS PRM Only
Analysis of All Resources at 17% PRM That Provide Regulation and Load Following							
Total of all Regulation Ranges (MW)	18,237	22,288	21,271	19,627	18,837	18,237	20,124
Total of all Load Following Ranges (MW)	25,418	33,458	31,448	28,178	26,618	25,418	29,078
Total of all Regulation Capability (MW in 10 minutes)	5,214	9,265	8,248	6,604	5,814	5,214	7,101
Total of all LF Capability (MW in 20 minutes)	11,771	19,811	17,801	14,531	12,971	11,771	15,431
Ratio: Total of all Reg Capability to Total of all Ranges (%)	28.6%	41.6%	38.8%	33.6%	30.9%	28.6%	35.3%
Ratio: Total of all LF Capability to Total of all Ranges (%)	46.3%	59.2%	56.6%	51.6%	48.7%	46.3%	53.1%

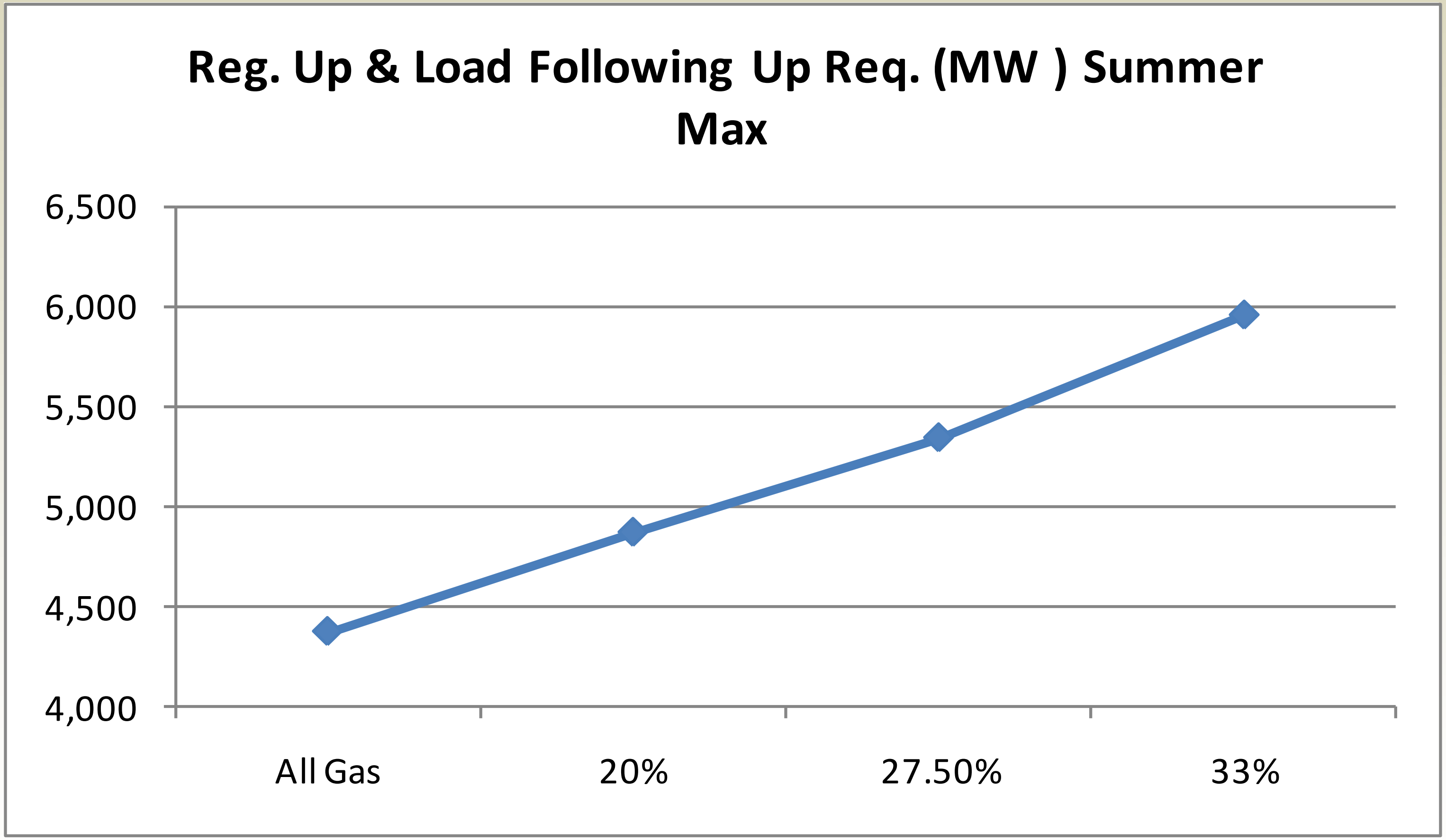
Analysis of generation fleet flexibility in 2020 (5)

Case Name		All Gas Final	20% Final	27.5% Final	33% Final	High DG PRM Only	High OOS PRM Only
Analysis of All Resources at 17% PRM That Provide Regulation and Load Following							
Total of Regulation Ranges (MW)		22,288	21,271	19,627	18,837	18,237	20,124
Percent Reduction From All Gas			4.6%	11.9%	15.5%	18.2%	9.7%
Total of all Load Following Ranges (MW)		33,458	31,448	28,178	26,618	25,418	29,078
Percent Reduction From All Gas			6.0%	15.8%	20.4%	24.0%	13.1%
Total of all Regulation Capability (MW in 10 minutes)		9,265	8,248	6,604	5,814	5,214	7,101
Percent Reduction From All Gas			11.0%	28.7%	37.2%	43.7%	23.4%
Total of all LF Capability (MW in 20 minutes)		19,811	17,801	14,531	12,971	11,771	15,431
Percent Reduction From All Gas			10.1%	26.7%	34.5%	40.6%	22.1%
Ratio: Total of all Reg Capability to Total of all Ranges (%)		41.6%	38.8%	33.6%	30.9%	28.6%	35.3%
Percent Reduction From All Gas		0.0%	6.7%	19.1%	25.8%	31.2%	15.1%
Ratio: Total of all LF Capability to Total of all Ranges (%)		59.2%	56.6%	51.6%	48.7%	46.3%	53.1%
Percent Reduction From All Gas			4.4%	12.9%	17.7%	21.8%	10.4%

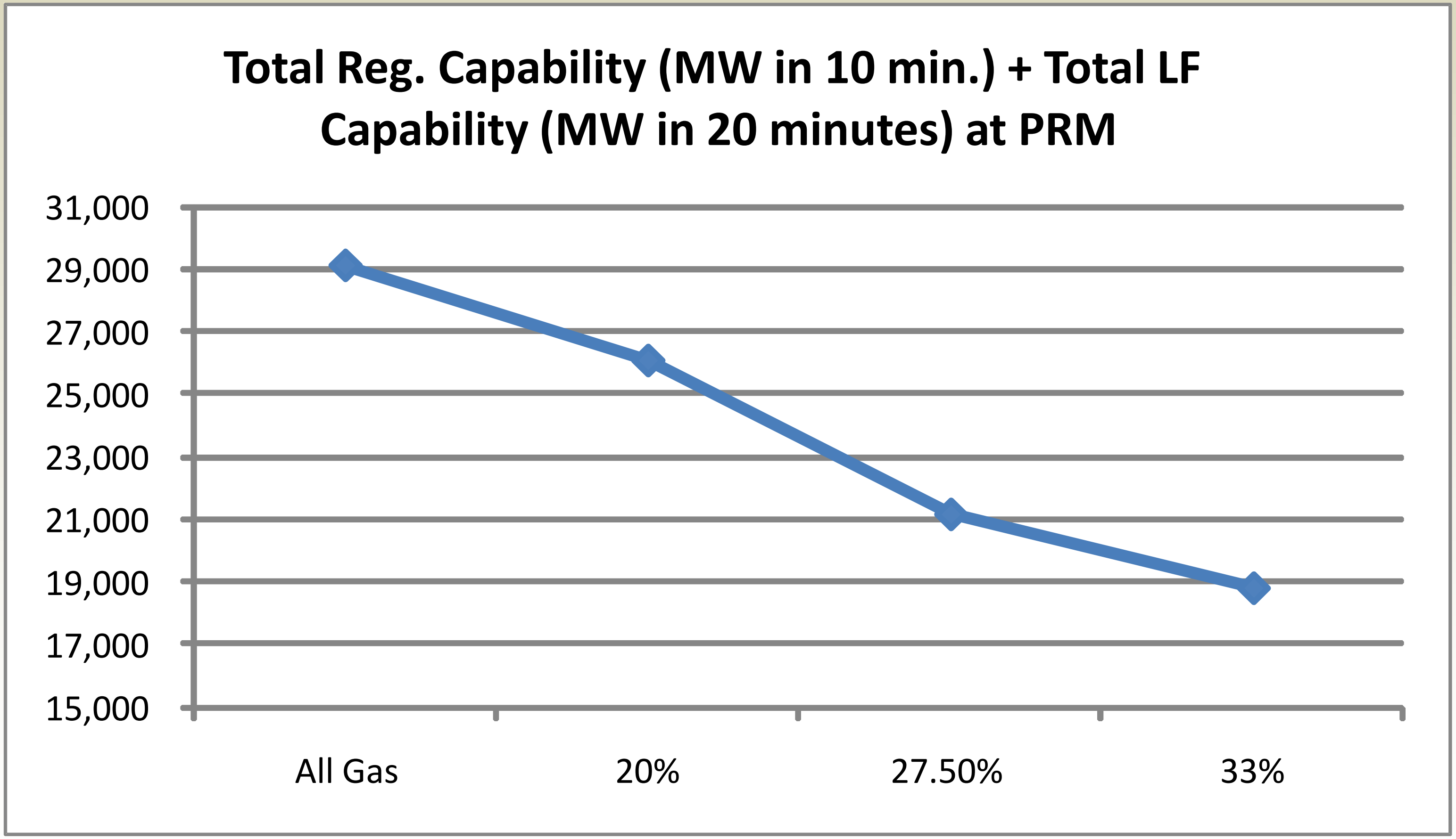
Analysis of generation fleet flexibility in 2020 (6)



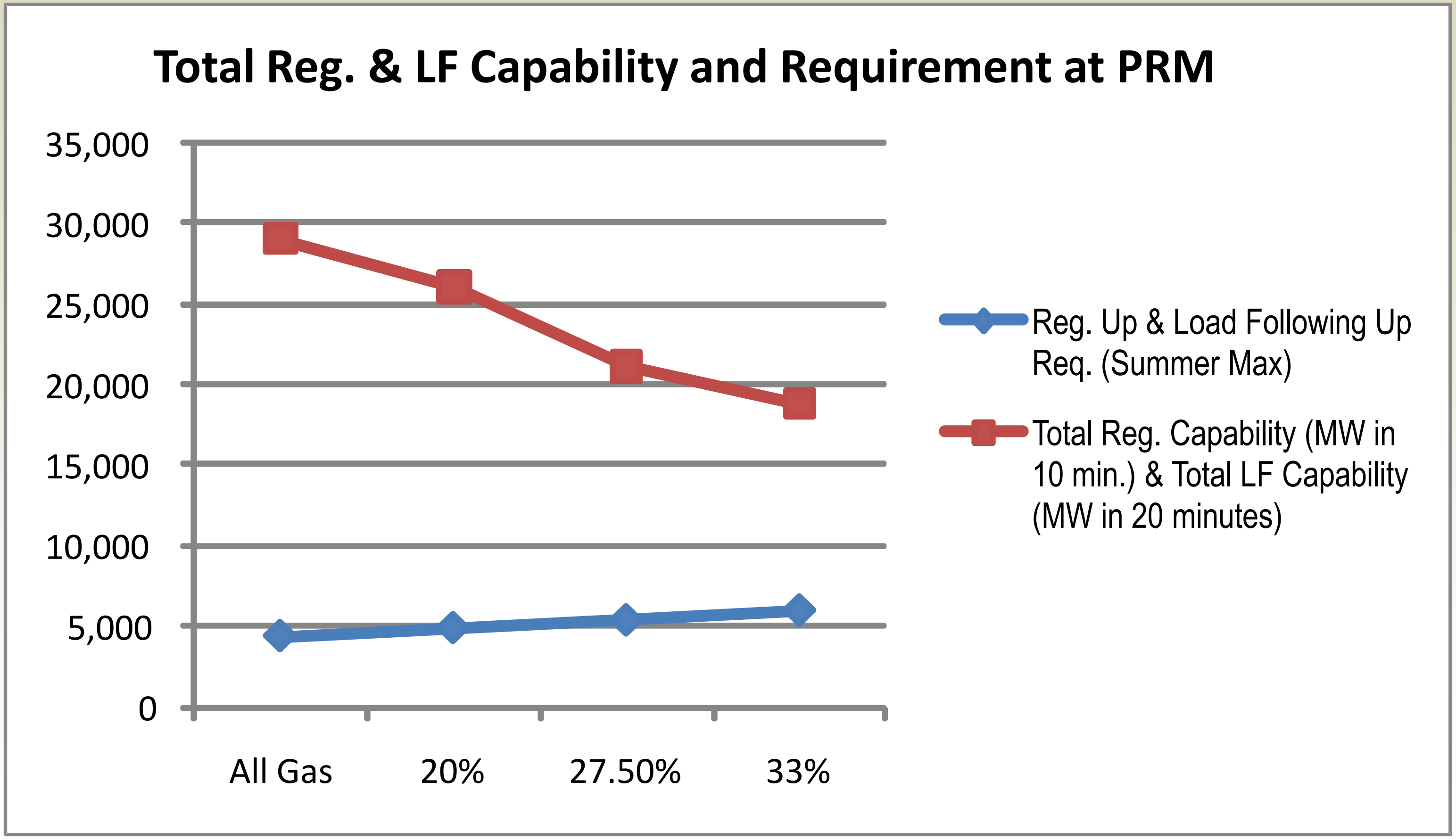
Analysis of generation fleet flexibility in 2020 (7)



Analysis of generation fleet flexibility in 2020 (8)



Analysis of generation fleet flexibility in 2020 (9)



STATUS OF PRODUCTION SIMULATIONS AND NEXT STEPS

Reasons for not releasing results today

- Long solution times resulted in scenario results only being available about a week before this workshop
- Data and results needed additional quality assurance evaluation
  - Queries have to manage large quantities of data; ensure that we are pulling the right data
- Impacts of certain modeling assumptions, such as those discussed earlier today require further evaluation
- ISO believes that 3-4 weeks of additional sensitivities and checking of results will be complete and allow for further validation of the results

Q & A